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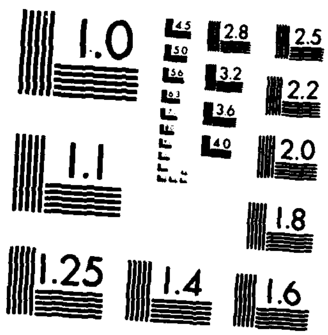

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PROGRESS REPORT

Metallurgical Characterization of the Interfaces and the Damping Mechanisms in Metal Matrix Composites

Contract No. N00014-84-C-0413

Submitted to: Dr. Steve G. Fishman
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Denver, Colorado 80201

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I. Contract Information

I.a. Title: Metallurgical Characterization of the Interfaces and the Damping Mechanisms in Metal Matrix Composites

I.b. ONR Contract Number: N00014-84-C-0413

I.c. ONR Work Unit Number: 039-269

I.d. Principal Investigator: Mohan S. Misra, Martin Marietta Aerospace, Denver, CO

I.e. ONR Scientific Officer: Dr. Steven G. Fishman

I.f. Period Covered: 10/1/85 — 9/30/86

II. Research Description

II.a. Description of Research

II.a.1 Introduction

Fiber reinforced metal matrix composites (MMC) are candidate structural materials for space applications because of their high specific modulus, low CTE, high electrical and thermal conductivity, and high environmntal resistance. In addition, high inherent damping is a matierial property requirement to meet the need for dynamic dimensional precision and weight savings in space structures. A preliminary investigation indicates that MMC exhibit improved damping with respect to conventional structural alloys of aluminum or titanium.

In the present investigation, a graphite-aluminum composite (P55/6061) has been selected to study the microstructural features and mechanisms responsible for damping in MMC.

II.a.2 Objectives

The objectives for this reporting period have been

i) Establish a reliable test method and its limitations
ii) Develop reproducible damping test data at different frequencies and strain amplitudes
iii) Thorough metallurgical characterization of interfaces
iv) Suggest an operative damping mechanism in MMC
v) Recommendations for further investigations

II.a.3 Technical Approach

i) Fabricate Specimens with Predefined Interfaces.
- — Fiber Matrix Interface Study
  - — P55Gr/6061Al precursor wires
    - — as received
    - — shear deformed
- —Diffusion Bonded Interface Study
  - — P55Gr/6061Al composite panels
    - — standard, state-of-the-art bonding
    - — imperfect bonding (reduced consolidation temperatures/pressures)

Letter on file.

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II.b. Significant Results in the Last Year

II.b.1 Introduction

During this investigation, methodology to measure damping by clamped free flexure and uniaxial tension-tension test techniques were developed, as stated earlier in Issue 3.

II.b.2 Establish Reliable Test Method and Its Limitations

Free-Free Flexure: A test apparatus was developed to measure the damping capacity of metal matrix composites in free-free flexure as shown in Figure 1. Allowances were made for damping measurements to be made in vacuum. Strain amplitude was kept below 10^{-4}. Damping measurements were made using the half-power method described in Figure 2. Test frequency depended upon specimen geometry and material properties. In addition, extraneous energy losses were minimized due to the nature of the specimen support as compared to clamped-free flexure.

II.b.3 Develop Reproducible Damping Test Data at Different Frequencies and Strain Amplitudes

Free-Free Flexure: Preliminary data taken in air, as well as uncertainties for these data, for 6061Al/6061Al composites are given below:

Material	Sweep Direction	Fundamental Frequency (Hz)	Damping Ratio ζ
6061Al/6061Al [0°]	Forward	61.49	0.00435
"	"	61.48	0.00435
"	"	61.47	0.00420
"	"	61.49	0.00435
Average		*61.48±0.010*	*0.00431±0.00008*
"	Reverse	61.45	0.00470
"	"	61.46	0.00465
"	"	61.46	0.00460
Average		*61.46±0.006*	*0.00465±0.00005*

A number of tests were conducted with frequency scanning in both directions to determine the uncertainty in damping data. First mode frequency determination was very precise while the damping capacity obtained with the half-power damping measurements varied with the direction of the frequency scan.

II.b.3 Metallurgical Characterization of the Interfaces

P55Gr/6061Al composite specimens were examined by transmission electron microscopy (TEM) to observe the dislocation substructure, precipitate morphology, impurities, nature of bonds, etc., adjacent to the fiber-matrix interface. Figure 3 shows the tangled dislocation substructure in the matrix region near the interface in a composite specimen subjected to cyclic vibration for damping measurement. In almost all the regions observed, the fiber matrix interface showed good bond and no voids. Three types of distinct precipitates; i) lathlike, ii) cuboidal and iii) blocky shaped, with similar composition were also observed in the matrix region.

II.b.4 Operative Damping Mechanism in MMC

Damping data from single-ply P55Gr/6061Al [0°] exhibited an increase in damping with increasing strain amplitude. This effect was more pronounced in the extensional mode. Experimental data and microstructural characteristics indicate that both the aluminum alloy and energy dissipating sources operating at the fiber matrix interfaces may have contributed significantly to material damping. These test results were analyzed in terms of the strain amplitude dependent Granato-Lucke (G-L) model (Fig. 4) which is based on dislocation breakaway from minor pinning

points. Application of this model to determine the mobile dislocation densities agreed with the densities measured from electron microscopy ($\rho > 10^6/cm^2$), suggesting dislocation motion as the operative damping mechanism in the strain amplitude dependent damping region.

II.b.5 Summary

The following is a summary of the results of work conducted within the reporting period:

i) Preliminary results with free-free flexure indicate that this method can be used sucessfully to measure damping in metal matrix composites.
ii) TEM of Gr/Al composites show that dislocations adjacent to the fiber matrix interface are tangled. These dislocations probably are the result of residual stresses, associated with the thermal expansion mismatch of the fiber and matrix during the fabrication process.
iii) Strain amplitude dependent damping is the result of dislocation motion and correlates well with the Granato-Lucke theory of dislocation damping.

II.c. Plans for the Remainder of the Contract

II.c.1 Final Report

II.c.2 Recommendations for Further Research

II.d. Presentations

II.d.1 Invited Presentation at Topical or Scientific/Technical Society Conferences

i) A.K. Ray, V.K. Kinra, S.P. Rawal and M.S. Misra, "Specific Damping Capacity of Metal Matrix Composites in Tension-Tension Fatigue," Vibration Damping Workshop, March 6, 1986, Las Vegas, Nevada p. FC1-FC16
ii) S.P. Rawal, J.H. Armstrong, M.S. Misra, A.K. Ray and V.K. Kinra, "Damping Measurements of Gr/Al Composites", Symposium on Dynamic Behavior of Composite Materials, Components and Structures, sponsored by the Society for Experimental Mechanics, New Orleans, June 12, 1986.
iii) S.P. Rawal, J.H. Armstrong and M.S. Misra, "Interfacial Characterization and Damping in Metal Matrix Composites," to be presented at the 11th Annual Conference on Composites and Advanced Ceramic Materials, Cocoa Beach, FL, Jan. 1987.
iv) S.P. Rawal, J.H. Armstrong and M.S. Misra, "Dislocation Damping in Gr/Al Composites," to be presented at 116th Annual Meeting of The Metallurgical Society, Denver, CO, March 1987.

II.e. Technical Reports

— none

II.f. Publications

i) S.P. Rawal and M.S. Misra, "Charcterization of Interfaces in Metal Matrix Composites," to be published in Journal of Metals, October 1986.

II.g. Honors, Awards

— none

II.h. Participants

Mr. Asok Ray; Graduate Student working towards his Ph.D. Thesis.
Advisor: Dr. V.K. Kinra at Texas A&M University, College Station, Texas

II.i. Other Sponsored Research

II.i.1 Title: Damping in Metal Matrix Composites
Sponsor: Martin Marietta Denver Aerospace
Amount: $60k

II.i.2 Title: Novel Processing Techniques of Gr/Mg Composites
Sponsor: DARPA
Amount: $1.9M

II.i.3 Title: Role of Interfaces in the Damping Characteristics of Metal Matrix Composites
Sponsor: ONR
Amount: $199k

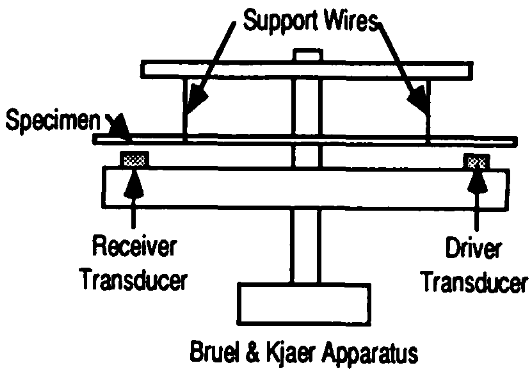

Figure 1: Schematic of Free-Free Flexure Test Apparatus.

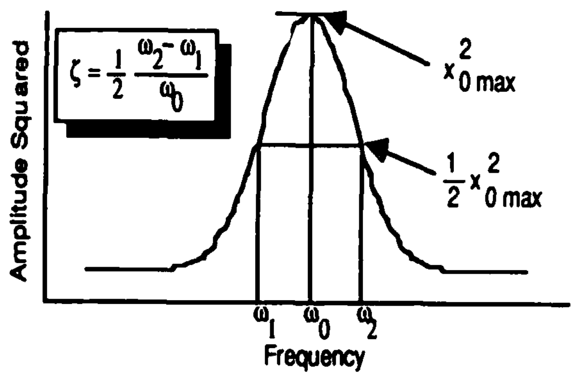

Figure 2: Half-Power Method for Obtaining Damping Capacity.

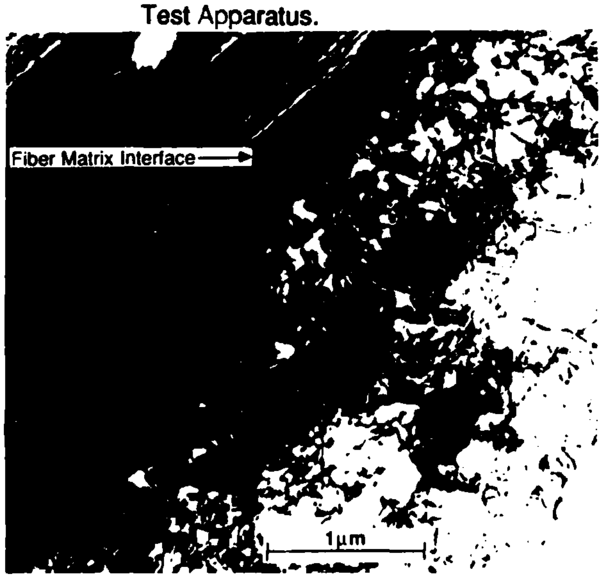

Figure 3: TEM Micrograph of P55Gr/6061Al Indicating Tangled Dislocation Structure.

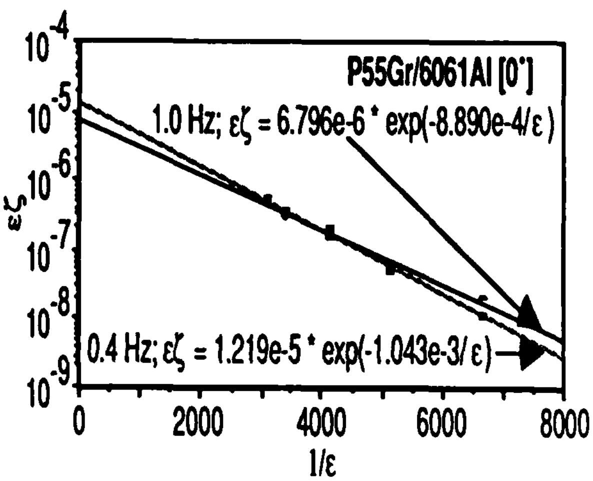

Figure 4: Granato-Lucke Plot of Uniaxial Tension-Tension Data Indicating Dislocation Motion is Responsible for Strain Amplitude Dependent Damping.

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